THE ELECTRICITY OF THE TORPEDO[1]

II.

4. *CURRENTS induced by a torpedo discharge are all produced at the beginning of each wave. There are currents induced on the completion of a circuit,* i.e., *the inverse of the inducting currents, as is shown by the electrometer.*

Fig. 7 will show the arrangement of the experiment to prove that the torpedo's discharge in the inductive coil

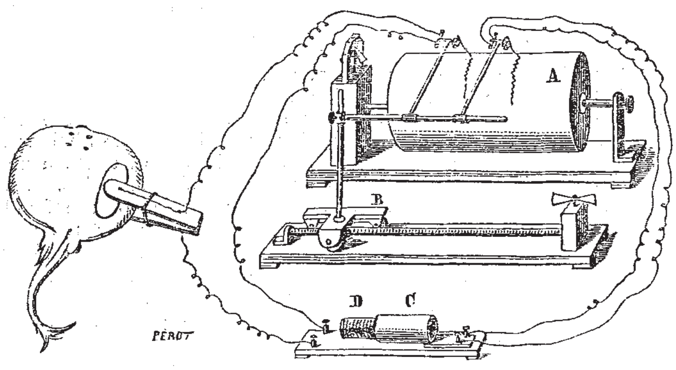

Fig. 7.

(D) produces, in the secondary coil (C) currents of sufficient energy to cause movement in the second signal placed in the circuit of the inducted coil. It must be remarked, however, that the electric apparatus which furnishes the indications of the passage of the discharge is not, as shown in the diagram, that which produces the inducted currents. Currents of sufficient intensity would not have been obtained to act upon the electro-magnetic signal, if we had opposed to the passage of the discharge a resistance so considerable as that of the coils of the electro-magnet. The difficulty has been averted by using the opposing apparatus for signalling; and this we are authorised in doing, since the discharges are absolutely symmetrical to the right and left when the nervous centres are excited by the magnet.

That exception made, let us examine the results of the experiment. The traces were placed one over another; one (as 1 in Fig. 8) indicating the successive waves of the discharge, and the other (as 2 in Fig. 8) the currents inducted by the waves. This figure already shows an important fact: that the number of inducted currents is equal to that of the inducting waves; and that each inducted current is produced at the commencement of each wave, just as in a galvanic current an inducted current is produced at each completion. But here we only find currents inducted by the completion or, more exactly, at the commencement of the waves; none are produced during the decreasing phase of each wave, or at least if they are produced they do not act upon the electro-magnetic signal.

From the preceding it should be inferred that the currents, inducted by the torpedo-waves and produced at the commencement of these waves, must in that be analogous to the inducted currents resulting from the completion of a galvanic circuit.

No instrument could be better than Lippmann's electrometer for giving us information as to the direction of the currents inducted by the torpedo waves. Its instantaneous action enables it to indicate, by a sudden displacement in a determinate direction, the direction of each inducted current.

If a weak current derived from the main discharge is passed through the electrometer, we see the column after moving to one side of the reticule always oscillate to the same side, thus showing that the successive waves are

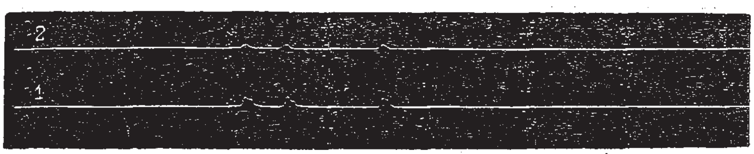

Fig. 8.

joined one to another, so that there is never an absolute break in the current. In Fig. 9 the arrows show the oscillation of the column towards the right side.

If the induced currents are directed through an electrometer by the discharge which causes the column of the instrument to deviate to the right, the direction of oscillation is immediately reversed (Fig. 10).

The comparison of those two diagrams showing that the inducted current has a contrary effect to that of the inducting current, brings together the inducted currents of the torpedo and those obtained by completing a galvanic circuit. To be more exact, since the circuit which comprises the torpedo remains always complete, we shall say that the inducted currents are produced at the beginning of each electric wave of the animal. Thus the torpedo calls forth in each of its electric waves an initial inducted current and does not give a terminal inducted current. This conclusion goes to support what we learned from the wave-writing of the electro-dynamograph, viz., that the initial phase of each wave has a suddenly increasing intensity, whereas the terminal phase presents a gradual decrease.

5. *The discharge of the torpedo is analogous to muscular tetanus; every electric wave in the discharge corresponds to a muscular shock.*

In what precedes we have endeavoured to give an idea of the torpedo discharge from the nature of the successive acts which constitute it, insisting only upon points relating to experimental science and to the direct results of M. Marey's investigations.

We are now enabled to meet the question on higher

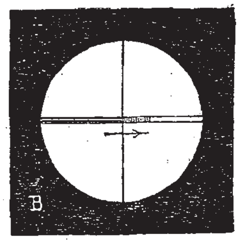

Fig. 9.

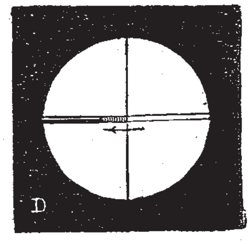

Fig. 10.

ground and consider the electric function from a philosophical point of view, by classing it with the muscular function.

Let us first compare the elementary action of electric discharge to the elementary action of muscular contraction, *i.e.,* the electric wave to the muscular shock.

[1] Continued from p. 297.

The simple excitation of the remote end of an electric nerve produces a single wave, as the simple excitation of a motor nerve produces a single shock. In both cases, at the moment of the nerve-excitation produced in the neighbourhood of the electric apparatus or of the muscular apparatus, the amount of delay is sensibly the same, about seven-hundredths of a second. The electric wave, like the muscular shock, has a phase of increase and a phase of decrease; the former, as we have seen, is abrupt or sudden from one part to another; the decreasing phase is much more gentle. The same agents modify the wave and shock in the same manner; heat renders both these actions more speedy and more energetic up to a certain point at which both electric reaction and muscular reaction disappear; cold acts equally upon movement and electric action, rendering both more slow, more feeble, more extended, and at last extinguishes them when the temperature is lowered to about zero C.

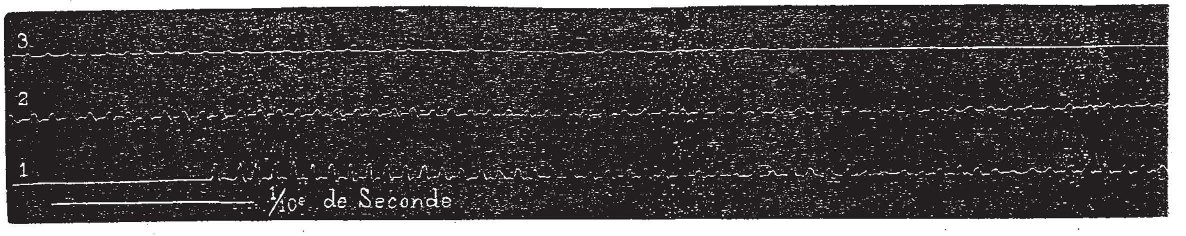

FIG. 11.

In the complex muscular act which is called contraction, as in the electric act which constitutes the discharge, the elementary phenomena which we have just been comparing, the waves and the shocks are added on one to another in the same manner; they succeed each other with a rapidity so great that each has not time to complete all the phases before its successor is produced. The floor and the shock are interrupted during their decreasing period by a new wave or shock coming to join on its

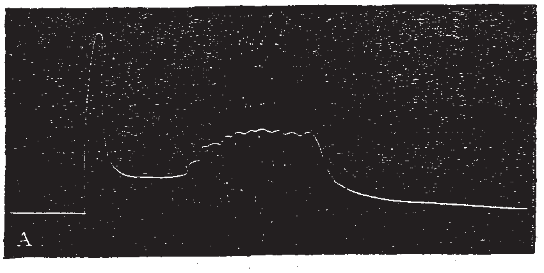

FIG. 12.

effect to what remained of the preceding act. But, as there are imperfect muscular contractions, cases of tetanus where the shocks are not completely fused together, not being rapid enough in their succession, so in the same way certain electric discharges present a remarkable discontinuity, such that the elements of the perfect act are seen arranging themselves, the waves following each other with less rapidity, the shocks separated from each other by a larger interval of time.

Let us now compare the effects of fatigue upon muscular contraction and upon the discharge, as we have compared them upon the muscular shock and upon the electric wave; we shall see the two acts modified in the same direction. It is even possible to see the torpedo-wave and discharge gradually becoming extinguished, just as muscular shocks disappear under the influence of exhaustion. This gradual extinction of the electric waves is very evident in Fig. 11, obtained by means of the electro-dynamograph.

Poisons which act directly or indirectly upon the muscular function modify in the same manner the electric function. Thus strychnine, for example, which in a very special manner exaggerates the excito-motor power and that which might be termed the excito-electric power of nervous centres; a complex reaction, a muscular tetanus on one side and a real electric tetanus on the other, is produced in reply to a simple excitation, the mere touch of the skin, or a slight noise.

Fig. 12 shows a type of muscular strychnine contraction in the frog. Here we observe a diminution of intensity produced in the middle of the muscular tetanus between two maxima, one at the beginning and the other at the close.

In agreement with this characteristic phenomenon, the cause of which is unknown, we observe in torpedo poisoning by strychnine a weakening or interruption towards the middle of the discharge. Fig. 13 shows on line A a type of this species of interruption which must be compared with that which we have just seen on the tracing of muscular tetanus.

We might still further extend the comparison of those two functions, the electric and the muscular, by studying the action of other fishes, such as the *Gymnotus*, the electric ray, &c.; and by showing that the results are identical when heat and cold act upon muscular contraction and upon the discharge of the torpedo. The preceding paragraphs are sufficient to justify the functional assimilation which, let us hasten to say, is in accordance with the anatomical assimilation.

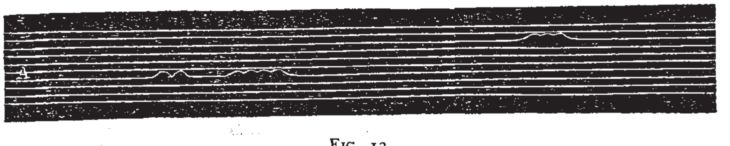

FIG. 13.

We shall only add that these identifications are of higher interest than curiosity; the more our knowledge of muscular phenomena and electric phenomena becomes perfected, the more enlightened is our knowledge of the motor nerves. Does the fact that a voluntary discharge of the torpedo is a complex act not prove that the voluntary contraction of the muscles is also a complex act? Very certainly, the comparison of the voluntary contraction of the muscles with the tetanic phenomena produced by electricity or by strychnine, the existence of a muscular sound during the contraction, the quivering or

dissociation of the shocks which are produced under the influence of cold, all these seem arguments in favour of the theory which considers muscular contraction as the result of very frequent shocks; but the complexity of the voluntary discharge of the torpedo, the manner in which the waves composing it succeed each other and are added together, forms a very important confirmation of the numerous presumptions already made.

FRANCOIS FRANCK

SCIENCE IN LANCASHIRE AND CHESHIRE

AT Liverpool the annual associated *soirée* of the Literary, Scientific, and Art Societies, eighteen in number, of which twelve are scientific, held at St. George's Hall on the 31st, was a marked success, and will tend much not only to foster scientific tastes in this district, but inculcate an element of scientific co-operation, in the various institutions of the town, that will be of the highest practical value. The fourteenth Winter Course of Free Lectures for the People, given at the Free Library and Museum, by order of the Corporation, commenced on the 6th of last month. Amongst the forty-one lectures announced, thirteen are on scientific subjects, given by the Rev. W. H. Dallinger, Mr. Moore (Curator), Mr. De Rance, Rev. H. H. Higgins, and others. The Liverpool Geological Society is also doing good work; a valuable paper on the carboniferous limestone of Denbighshire was lately read by Mr. Morton, and a short but important mineralogical paper was given by the President, Mr. Semmons. Geological knowledge has been increased by a boring at Bootle, sunk to determine the water-bearing properties of the new red sandstone at great depths, by Messrs. Mather and Platt, for the Liverpool Corporation, who were urged to this course by Alderman Bennett. The boring has reached a depth of 1,300 feet, is 25 inches in diameter, is filled with water up to a height of 50 feet from the surface, and, according to Messrs. De Rance and Morton, has proved the pebble beds of the Bunter to reach the extraordinary thickness of 1,200 feet, and the existence of the lower mottled sandstone beneath. The pumps not yet being fixed, it is impossible to judge how far the well will add to the supply of 6,000,000 gallons a day at present pumped from the corporation wells.

At Wigan, in addition to the ordinary course of lectures given at the Mining and Mechanical School, a special course has been arranged for candidates for colliery managers' certificates, and gives to the teaching of the school a special technical direction. The extension scheme for turning the very numerously attended evening classes of this school into a Mining Collegiate Centre for Lancashire, has necessarily languished under the unexampled and continued depression in the coal trade, though from the number and extent of the promised subscriptions and donations to the building-fund, there can be little doubt that, when better times again visit this country, this school will develop into an important centre of technical education. The town has lately had the good fortune to have presented to it a magnificent library, stored in a handsome building erected for the purpose, the former being the bequest of the late Mr. Winnard, the latter the gift of Mr. Thomas Taylor. The reference library is well stored with standard scientific works in all branches, and the selection reflects great credit on the industry and acumen of Mr. Gerrard Finch, barrister-at-law, who selected them, under the terms of the will. Some important works are of course conspicuous by their absence, but doubtless this will soon be remedied. The reference portion of this library will henceforth be opened on a Sunday to readers who have asked for special tickets, the extra cost of assistants being defrayed for three years by Mr. Taylor, the donor of the building. This town has also now a flourishing Literary and Scientific Society, with Lord Lindsay as president; it is divided into botanical, microscopical, and other sections, at which papers are read by the members, and discussed, and, in addition, special lectures are given to the united sections; amongst those delivered have been "Spectrum Analysis," by Lord Lindsay, and "Local Geology," by Mr. de Rance: others are announced by Prof. McKenny Hughes and Prof. Rudler.

At Southport there is at present little done for fostering a taste for either technical or scientific education, but the very fine aquarium is maintained in great efficiency, the contents of the table tanks, to which we have previously referred, being especially beautiful.

At Preston, meetings of the Scientific Society have been numerously attended, and the president, Dr. Arminson, and others, do good microscopical work. The meetings are held at the Avenham Institution, which is well filled with scientific works, including the natural history library of a defunct Naturalists' Society, and it is a matter of regret that the town, in adopting the Free Libraries Act, should not have carried out an amalgamation scheme, instead of running a new and inefficient library in opposition to the existing useful and self-supporting institution. The Gilchrist Trust lecturers here and at Burnley have been listened to with much interest by large audiences; and at the latter place Prof. Boyd Dawkins has inoculated his hearers with his taste for cave-hunting investigations, and searches have been organised into the wild hills which fringe the county boundary of Lancashire and Yorkshire, and form the backbone of England, a district which for the most part appears to be above the level of the glacial sea deposits.

At Chester the flourishing Natural Science Society that looks back with pride to Kingsley, its founder, and forward with hope to its president, Prof. McKenny Hughes, is divided into several sections like a small British Association. The most noticeable paper read was one by Mr. Shrubsole, on the Fenestellæ of the carboniferous limestone, which was an important and valuable contribution to our knowledge of this group, proving from perfect specimens that several supposed species are, in fact, portions of the same organism. General lectures have been given to the united sections by Prof. Judd and Mr. De Rance, who opened the winter session. The Society possesses a very good local museum, but unfortunately it is exhibited in the disused ball-room of an ancient hotel in an out-of-the-way part of the city, and is known to few of the scientific visitors of Chester, and is but seldom visited by the inhabitants. The collection would, however, form an admirable nucleus of a museum for teaching purposes, should the Corporation ever recognise the need of technical education in this town, and erect a building to hold a library, museum, and science and art schools by the side of their fine town hall. Towards filling museums of this class, great advantage would accrue if the duplicate specimens at the British and Jermyn Street Museums were either given, or allowed to circulate, in the same manner as the art treasures from South Kensington Museum. For valuable as are *local* collections for the scientific *specialists*, no one can doubt the importance of giving wide and varied knowledge to the general public, such as, perhaps, can only be imparted by the inspection of typical specimens of the natural and artificial products of all countries. Such a collection may be seen on a small scale in the admirable little museum at Castleton, in Derbyshire, formed by Mr. Rooke Pennington, which at once furnishes the visitor with all that can be collected for forming a mental local picture of the past, and affords the inhabitants of the district an opportunity of knowing something of the world around them.

At Manchester the museum at Owens College now includes the entire collections of the Manchester Natural